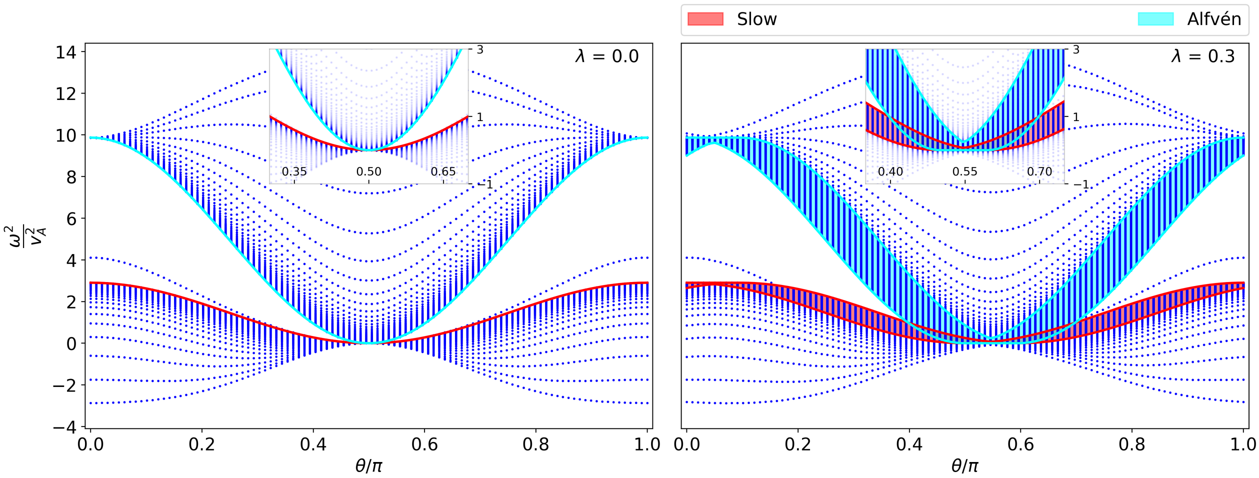
4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Legolas: a novel 1D finite element MHD spectral code

N. Claes, J. De Jonghe, R. Keppens
Centre for mathematical Plasma-Astrophysics, KU Leuven, Belgium
e-mail (speaker): niels.claes@kuleuven.be



Legolas is a newly developed numerical code, able to calculate the magnetohydrodynamic spectrum of 1D equilibria with non-adiabatic effects, resistivity, gravity and flow. Inspired by early numerical tools such as LEDA [1] and LEDAFLOW [2], Legolas is the first 1D spectral code to combine all aforementioned physical effects into a modern and versatile spectral framework. This allows for advanced studies of linear stability theory, as the MHD equations are Fourier-transformed into a set of linearised equations which are solved using a Finite Element Analysis. The mathematical formalism is constructed in a general form such that both Cartesian and cylindrical geometries can be investigated using the same implementation by making use of a scale factor originating from the standard mathematical operators. The finite element approach transforms the original set of equations into a matrix eigenvalue problem which is solved using general techniques. For the moment Legolas uses a QR-algorithm to calculate eigenvalues and corresponding eigenvectors, which in turn gives us information on the general stability of various eigenmodes in a specific equilibrium configuration. An example is given in the figure above, where we show the spectrum of an exponentially stratified slab with (right) and without (left) magnetic shear, calculated using Legolas. We present a variety of test cases used to validate the new numerical tool where the use of high resolutions sheds new light on some previously calculated spectra, giving clear indications of interesting spectral regions that never have been investigated before. Understanding the stability of linear MHD modes can be directly connected to solar plasmas, where various works have shown that instabilities have a major influence on the general structure and dynamical development of e.g. prominences [3, 4, 5]. The inclusion of fully realistic treatments of radiative cooling and thermal conduction in Legolas allows for detailed studies of various plasmas, including the solar corona, and will no doubt shed new light on both the stability of coronal structures and their dynamical evolution.

References

[1] W. Kerner, K. Lerbinger & J. Steuerwald, "*Computing complex eigenvalues of large non-hermitian matrices*" (1985). Computer physics communications, 38(1), 27-37.
[2] RJ. Nijboer, B. Holst, S. Poedts & JP. Goedbloed, "*Calculating magnetohydrodynamic flow spectra*" (1997). Computer physics communications, 106(1-2), 39-52.
[3] N. Claes, R. Keppens & C. Xia, "*Thermal instabilities: fragmentation and field misalignment of filament fine structure*" (2020). Astronomy & Astrophysics, 636, A112.
[4] D. Yuan, Y. Shen et al., "*Multilayered Kelvin-Helmholtz instability in the solar corona*" (2019). The Astrophysical Journal Letters, 884(2), L51.
[5] A. Hillier, "*The magnetic Rayleigh-Taylor instability in solar prominences*" (2018). Reviews of Modern Plasma Physics, 2(1), 1.